Coupling Oyster and Future SAV Restoration; A demonstration project

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Introduction

Oyster (*Crassostrea virginica*) populations in Chesapeake Bay have witnessed serious declines in the past 100 years, due to disease, harvest pressure and degradation in habitat and water quality (MacKenzie, 1996). Oysters and their reefs provide many benefits to estuarine ecosystems, including filtering algae from the water column, improving water clarity, protecting shorelines from erosion and provide habitat to a variety of invertebrates and fishes (Newell, 2004). Based on estimates of historic oyster populations and the filtering capacity of oysters, it is believed that 120 years ago, oysters could filter the entire volume of the Chesapeake Bay in three to six days. Now, the remaining population would require a year to accomplish the same thing (Newell, 1988).

It is believed that if the Chesapeake Bay Oyster Restoration Goals in the Environmental Protection Agency Chesapeake 2000 Agreement were met by 2010, that benthic filtration would have dramatic benefits to SAV and other living resources. The oysters could remove suspended material (algae and sediments) from the water column, thus increasing light penetration to the bottom, critical for SAV survival and resurgence.

Like oysters, SAV populations are dramatically lower now than they have been historically (Orth and Moore, 1984). Based on a study of 1952 aerial photography that was taken for soil conservation mapping, 73,000 acres of SAV were identified in Maryland’s portion of the Chesapeake Bay (Naylor, 2002). A recent survey performed by the Virginia Institute of Marine Science (Orth et al., 2002) found approximately 31,000 acres of SAV in Maryland’s Chesapeake Bay in 2002, a decline of almost 60% since 1952. Taken together, oyster reefs and beds of submerged aquatic vegetation (SAV) are the two most important habitats in the Chesapeake Bay.

The concept of oyster reefs improving habitat sufficiently to allow re-establishment of adjacent SAV communities is gaining increased attention (http://www.mdsg.umd.edu/MarineNotes/Jan-Feb01/index.html), and several papers have been published exploring this hypothesis through models (Newell and Koch, 2004). However, no one has tested this potential in "real-life" settings in Chesapeake Bay.

We designed our project in Harness Creek, South River, Maryland to test the efficacy of oyster filtration in improving water clarity relative to the habitat requirements of submerged aquatic vegetation (Dennison *et al.*, 1993; Kemp *et al.*, 2004). Additionally, we hoped to gain insight into how practical multiple habitat restoration would be.

Methods and Materials;

Site selection

We surveyed several locations in fall 2002 to support a project using oysters to improve water quality. Sites were evaluated on these criteria;

- The site had to have the potential to support oysters (adequate salinity, low occurrence of disease (based on studies in adjacent areas)
- have a relatively small surface area (between 0.5 and 5 hectares)
- have a restricted opening so that the influence of adjacent waters on local water quality would be minimized
- have a firm bottom across the opening able to support of oyster shell and oysters
- be in an area closed to commercial oyster harvest
- have a reliable pool of citizen volunteers to help build an oyster reef

- Not have populations of SAV already in the area

We chose a small cove on Harness Creek, South River, Maryland (figure 1) that fit all these criteria. The total surface area of the site is approximately 1 hectare, with an average depth of 1 meter, containing approximately 9.25 million liters of water (including a 0.5-meter tidal amplitude). We found that the mouth of the cove had approximately 800 square meters of firm bottom, suitable for supporting oyster shell. The VIMS aerial surveys have not mapped SAV in the immediate area, and the cove is entirely within the riparian zone of an Anne Arundel County park (Quiet Waters Park), and therefore closed to shellfish harvest. Oysters thrive in the adjacent waters of Harness Creek and in South River. Also, the South River Federation (http://www.southriverfederation.net), a community based conservation group, is very active in Harness Creek and involved with oyster restoration projects.

Oyster reef creation

Maryland Department of Natural Resources Shellfish Division purchased 105 cubic meters of mined oyster shell. The Chesapeake Bay Foundation's *M/V Patricia Campbell*, an oyster setting boat, spread the material over the 800 square meters previously identified for the reef over three days in July 2003. A layer of fine material was placed first, and then a cap of whole shell was put on top of that. The South River Federation, working with the Oyster Recovery Partnership (http://www.oysterrecovery.org) placed 600,000 spat, 100,000 one-year-old oysters and 75 bushels (unfortunately no total number available) of two-year-old oysters on top of the shell substrate in October 2003. The Oyster Recovery Partnership provided the spat, while South River Federation oyster gardeners provided the one- and two-year-old

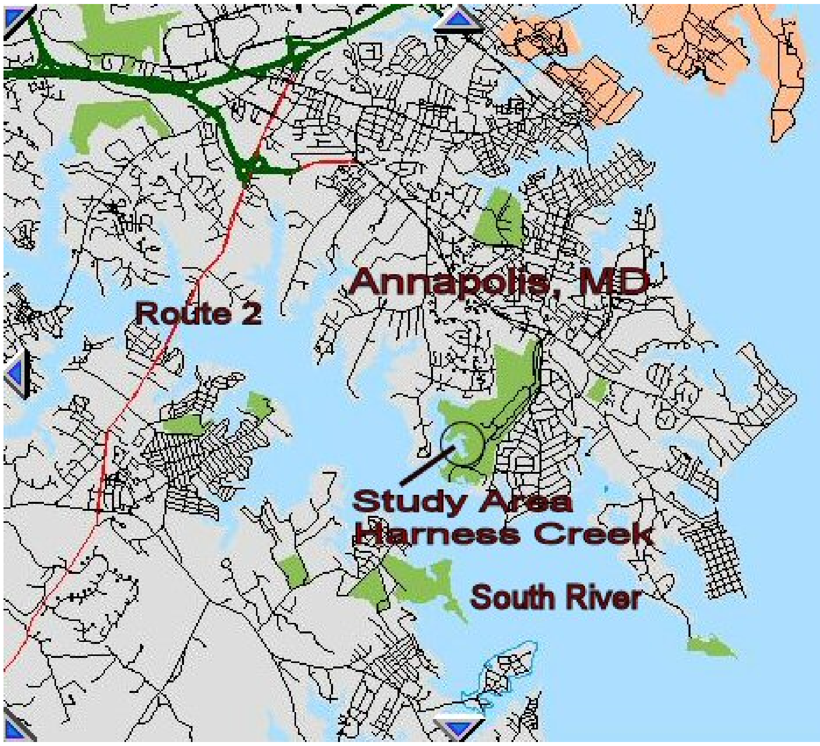

Figure 1; location of study site.

oysters. We estimated that this number of animals would be able to filter the entire volume in the cove twice daily (Newell, 1988, adjusted for a 2" animal using a geometric regression).

<u>Water quality monitoring</u>

To assess the impact of oyster filtration on water quality, a multi-part monitoring plan was established. We identified four stations (two on each side of the reef, one close to the reef, one more distant, figure 2) and began monitoring water quality in August, 2003 through October 2003 to establish water quality conditions prior to seeding the reef with oysters. We sampled each station for water temperature, dissolved oxygen, pH, conductivity and salinity using a Hydrolab water quality instrument. Secchi was measured and samples filtered for dissolved organic carbon, ammonium, nitrate, nitrite,

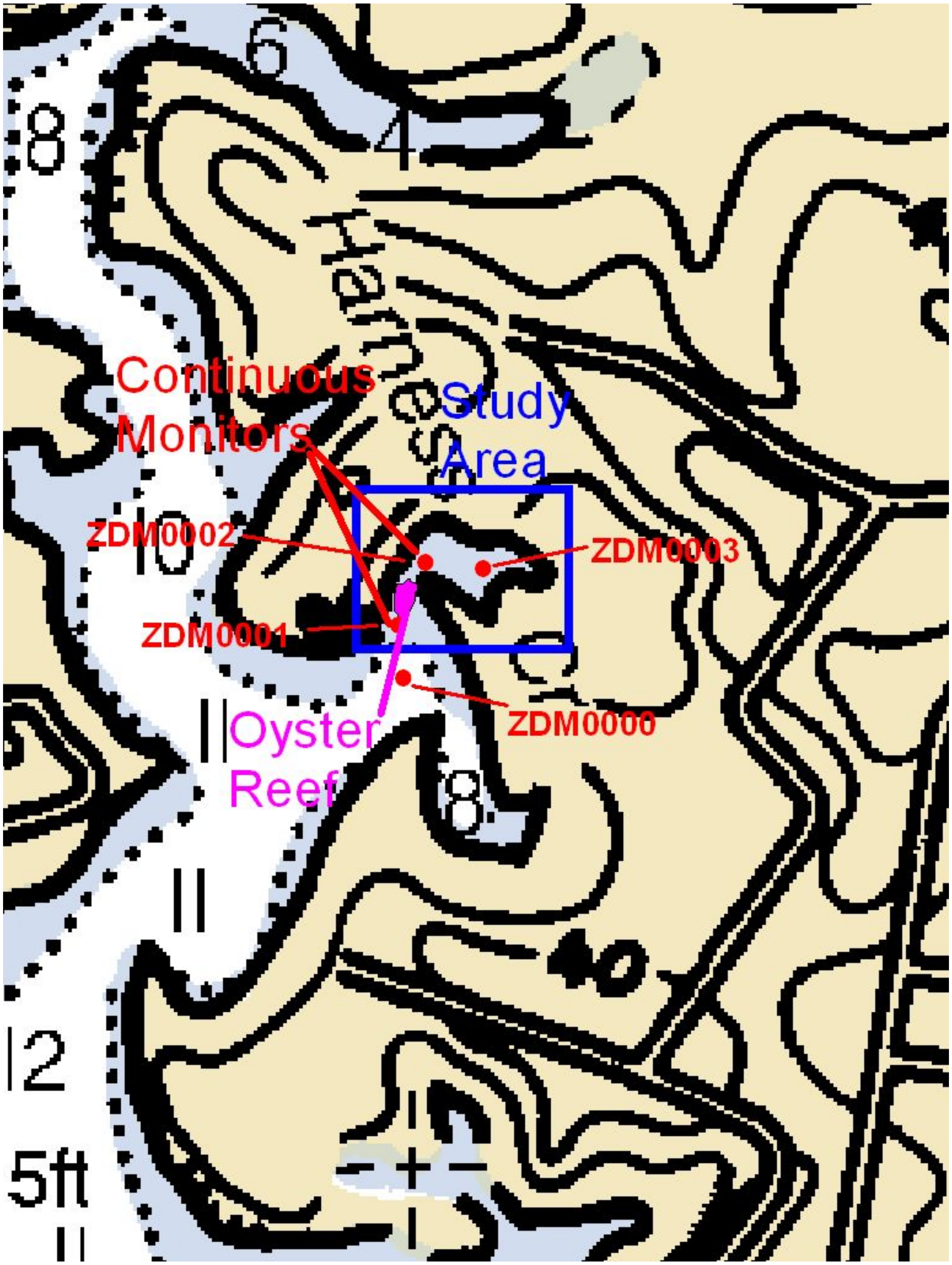

Figure 2, locations of oyster reef and monitoring stations.

particulate carbon, nitrogen and phosphorous, orthophosphate, total dissolved nitrogen and phosphorous, total suspended solids, chlorophyll *a* and silicate using methodologies of Maryland DNR's water quality monitoring program (Michael and Ebersole, 2001).

Chesapeake Biological Laboratory Nutrient Analytical Services performed the laboratory analyses. These stations are referred to as "discrete monitoring". Data are available at http://www.chesapeakebay.net/data/index.htm.

Beginning in April 2004, the same four stations were monitored as in 2003, though Maryland Deparment of Health and Mental Hygiene conducted the chlorophyll *a* analyses. Photosyntheticly Active Radiation was measured using a LiCor and YSI 6600 EDS units were installed on two pilings at the two stations closest to the reef on May 13th, 2004. The units measure depth, water temperature, turbidity, dissolved oxygen, pH, fluorescence, conductivity and salinity every 15 minutes (these data are referred to as "continuous monitoring" data). We deployed these instruments to assess water quality changes as water flowed across the reef during ebb and flood tides. Each instrument deployment lasted two weeks. We then replaced the unit with a freshly calibrated one, allowed each instrument to take two consecutive readings simultaneously (for comparison purposes), and then returned the previously deployed unit for cleaning and refurbishing. Data are attached.

Data were entered and stored using standard Maryland DNR protocols. Data analysis consisted of using Wilcoxon Rank Pairs for the continuous monitoring data and Kruskal-Wallace tests for the discrete monitoring data (Zar, 1984). All statistical tests were evaluated at $\alpha = 0.05$.

Results and discussion;

<u>Oyster health and survival;</u>

We surveyed the oyster reef on July 6th, 2004 for oyster survival and health. We collected all oysters from 1/9 m^2 quadrates in 10 randomly selected areas of the reef. The oysters were counted and measured. We found the median size of the oysters was 61mm and had approximately 13% mortality. The average density was 252 oysters/m. This is approximately 200,000 animals on the reef. This is significantly lower than what South River Federation placed on the reef. There are some ideas behind the discrepancy; the initial counts of spat were wrong, there was mortality not discovered by our sampling protocol or some of the oysters were poached. In fact, we did receive a call from a citizen claiming that he saw a waterman working over the reef, but we were unable to confirm this. However, 200,000 two-inch long animals should filter approximately 9.5 million gallons of water per day, roughly equal to the volume of water in the cove. Additionally, the density of 200,000 oysters over approximately 0.2 acres is similar to densities seeded on oyster sanctuaries in Chesapeake Bay, and therefore relevant to the goals of this project.

<u>Water quality monitoring</u>

Discrete Station Monitoring;

Nine water quality monitoring cruises were performed weekly in 2003 from August 28th through October 30th. Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorous (DIP) and Total Suspended Solids (TSS) median values passed the respective habitat requirements (Dennison et al. 1993), while Secchi depth and Active Chlorophyll *a* failed (CHLA) (table 1). The results of the Kruskal-Wallace test indicate that each of the four stations were statistically similar to one another for DIN, DIP, TSS, Secchi (CHLA?) (table 2).

Table 1; Medians for fixed station water quality monitoring, 2003 for SAV Habitat Requirement (HR) Assessment

Station	CHLA median µg/l (HR = 15)	DIN median mg/l (HR = 0.15)	DIP median mg/l (HR = 0.01)	TSS median mg/l (HR = 15)	Secchi median m (HR = 0.96)
ZDM0000	30.37	0.0137	0.0045	12.2	0.6
ZDM0001	30.54	0.0204	0.0046	13	0.6
ZDM0002	33.65	0.0085	0.0039	13	0.6
ZDM0003	31.65	0.011	0.0041	15.2	0.5

Table 2; Results of Kruskal-Wallace test on 2003 water quality data. Comparison is between all stations

Variable	Kruskal-Wallace Statistic	Degrees of Freedom	Probability
CHLA	2.165	3	0.5380
DIN	1.3485	3	0.7176
DIP	0.3543	3	0.9495
TSS	0.8250	3	0.8435
Secchi	2.2290	3	0.5263

Sixteen cruises were performed in 2004, starting on April 15th and continuing through October 27th. As in 2003, DIN, DIP and TSS median values passed the respective habitat requirements (Dennison et al. 1993), while Secchi and Chlorophyll failed (table 3). There results of the Kruskal-Wallace test indicate that each of the four stations were statistically similar to one another for DIN, DIP, TSS, Secchi and Chlorophyll (table 4).

Table 3; Medians for fixed station water quality monitoring, 2004 for SAV Habitat Requirement (HR) Assessment

Station	CHLA median µg/l (HR = 15)	DIN median mg/l (HR = 0.15)	DIP median mg/l (HR = 0.01)	TSS median mg/l (HR = 15)	Secchi median m (HR = 0.96)
ZDM0000	16.3225	0.0375	0.0026	15.3	0.7
ZDM0001	16.1980	0.0926	0.0024	18	0.55
ZDM0002	16.9455	0.0586	0.0038	15.3	0.6
ZDM0003	20.4340	0.0897	0.0031	17.3	0.6

Table 4; Results of Kruskal-Wallace test on 2004 water quality data. Comparison is between all stations

Variable	Kruskal-Wallace Statistic	DF_KW	Probability
CHLA	1.1528	3	0.7644
DIN	0.8216	3	0.8443
PO4	0.7741	3	0.8557
TSS	3.0427	3	0.3851
Secchi	3.0159	3	0.3892

When you compare the 2003 and 2004 data, there were significant differences between years for DIN and CHLA. DIN was significantly higher in 2004 than in 2003, while CHLA was significantly lower in 2004 than in 2003, declining by one-half to one-third. DIP, TSS and Secchi were statistically indistinguishable between years (table 5).

Table 5; Results of Kruskal-Wallace test comparing 2003 to 2004 water quality data. Probabilities in bold indicate a significant result

Station	CHLA (Probability)	DIN (Probability)	DIP (Probability)	TSS (Probability)	Secchi (Probability)
ZDM0000	**0.0098**	**0.0451**	0.2292	0.7133	0.5861
ZDM0001	**0.0046**	**0.0148**	0.4399	0.0450	0.9746
ZDM0002	**0.0007**	**0.0045**	0.3157	0.5254	0.6517
ZDM0003	**0.0417**	**0.0024**	0.6395	0.5257	0.8786

For DIP, TSS, and Secchi, the oysters present on the reef did not significantly improve the conditions in 2004 as was hoped, and DIN degraded between years. Chlorophyll, showed significant and dramatic improvements between 2003 and 2004. It is difficult to attribute this improvement solely to the oysters, but it is an encouraging result. However, metrological conditions cannot be accounted for, and changes in surface water discharge could explain the increased nitrogen concentrations and the decrease chlorophyll levels. With the possible exception of chlorophyll, the density of oysters in the study area, or their relatively small size (and filtration rate) appears to have been insufficient to improve water quality relative to the SAV habitat requirements.

Continuous monitoring

YSI 6600EDS continuous monitors were deployed on May 13, 2004 and swapped out every two weeks through October 27. Approximately 16,000 observations were collected over this time period. Data were analyzed using a Wilcoxon Rank Pair test, a non-parametric analog to the t-test. Data were analyzed as a complete dataset and then analyzed tidally, using the depth sensor information from the YSI's to determine local ebb, flood and slack tides. Only the analysis of the turbidity and fluorescence data is presented in table 6, as these are the parameters that would be most affected by the presence of oysters and the most relevant to SAV.

Table 6; Results of Wilcoxon Rank Pair test for the continuous monitoring data from stations ZDM0001 and ZDM0002. The medians displayed below are the median differences between the stations, as turbidity and fluorescence were not analytically determined. These differences were created by subtracting the values of ZDM0002 from ZDM0001.

Stage of Tide	month	*n*	Turbidity median	Turbidity Probability	Fluorescence median	Fluorescence Probability
Ebb	all	8231	-0.9	0.0000	-0.1	0.8597
Slack	all	297	-0.7	0.0000	-0.9	0.1643
Flood	all	7503	-0.6	0.0000	1.1	0.0000
all	all	16031	-0.8	0.0000	0.4	0.0000

These results suggest that the reef is having an impact on water quality. During slack water, both turbidity and fluorescence are statistically identical between the two sites. On the ebb tide, turbidity is greater at than inshore site (ZDM0002) than at the site across the reef (ZDM0001). On the flood tide, the offshore station (ZDM0001) still has less turbidity than the nearshore site, but the magnitude is approximately 0.3 NTUs lower than during the ebb. Fluorescence is even more dramatic, with the offshore site having slightly lower fluorescence values (0.1 µg/l total chlorophyll) than the inshore station during the ebb, but significantly higher chlorophyll values (1 µg/l) on the flood, a possible indication that the oysters are affecting the chlorophyll concentrations.

Conclusions;

Chlorophyll results indicate that the oysters may be having a beneficial affect on water quality in Harness Creek. The inter-annual analyses showed a dramatic improvement in chlorophyll concentrations between 2003 (the "before" condition) and 2004 (the "after" condition), though it is not possible to separate out reef effects from occurrences in the region. Additionally, continuous monitoring data indicate that chlorophyll *a* concentrations improve by about 1 μg/l after passing over the oyster reef. The other relevant SAV habitat requirements (DIP, TSS and Secchi) showed no significant difference between years or between stations, with the exception of DIN. DIN showed a significant increase from 2003 to 2004, but still did not exceed the habitat requirement. This study shows that oysters do have the capacity to alter the water quality (particularly chlorophyll) in the field, but intra-annual improvement in water quality is slight with this biomass of oysters. Inter-annual improvements may be more substantial, but our dataset wasn't adequate to attribute all the improvements seen to the oyster reef. With future funding, we hope to augment the oyster populations on the reef and repeat this study. We hope that the additional animals along with the current animals having grown larger will show more definitive results.

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